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13. ABSTRACT *(Maximum 200 words)*

In Balanced Incomplete Block Designs the presence of outliers in the data not only indicate non-normality, so that classical methods of analysis on the data are inappropriate, but also diminish the power of classical methods of analysis that assume normality of the data. One alternative is to use Durbin's nonparametric test. This research examined a rank transformation approach where all the data are ranked from smallest to largest, over all treatments and blocks. Then the usual F-test is computed on the ranks.

This rank transformation approach is asymptotically distribution-free, and is very powerful in cases where outliers are present as compared with both the parametric F-test and Durbin's nonparametric test. In the case of normality of the data it has only a slight loss of power. Thus it is a good alternative procedure to consider when analyzing data from a Balanced Incomplete Block Design.

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THE RANK TRANSFORMATION TEST FOR BALANCED INCOMPLETE BLOCK DESIGNS

FINAL REPORT

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MAY 24, 1997

U. S. ARMY RESEARCH OFFICE

GRANT NUMBER DAAL03-90-G-0066

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A. STATEMENT OF THE PROBLEM STUDIED

This research project investigated the possible use of ranks, in place of the original data, in the balanced incomplete block design. The analysis of ranks has been shown to be a powerful alternative to the classical analysis in some experimental designs, while at the same time it has been shown to be totally inappropriate in others. This project went on to study the appropriateness and the power of other scores based on ranks, such as the normal scores, and models other than the BIB design model.

The motivation for this program arose from data sets in which outliers were present. The presence of the outliers prevented the usual statistical techniques from finding significant differences between the treatments even when the data "obviously" showed significant differences to the casual observer. Some sample data sets with outliers indicated that the rank transformation might provide a more powerful method of analysis in such cases.

The approach used in this research program was to use the theory of mathematical statistics to show that the usual F statistic, calculated on ranks and other scores based on ranks, approaches the F distribution as the number of blocks becomes large. The asymptotic relative efficiency of these methods was found for random blocks using theoretical means. Also computer simulation was used to determine how close the F distribution approximates the exact distribution of the test statistic when the null hypothesis of equal treatments is true.

B. SUMMARY OF THE MOST IMPORTANT RESULTS

The first objective of the research proposal was to extend the theory of rank transformations to the balanced incomplete block design, so that the F statistic computed on the ranks of the data can be shown to have asymptotically the chi-square distribution divided by its degrees of freedom, as in the regular analysis of variance on the data. This objective was completed in August 1990.

The second objective was to compare the exact null distribution of the F statistic computed on ranks with the F distribution with t-1 and M-t-b+1 degrees of freedom. This objective was completed by a Graduate Research Assistant in December 1990.

The third objective was to study the power of the rank transformed F statistic as compared with other tests. This objective was completed by a Graduate Research Assistant in May 1991.

The fourth objective was to generalize the asymptotic results of the rank transformed F statistic to include scores other than ranks. This objective was completed in July, 1991, by arriving at the conditions required by the scores in order for the Lindeberg condition for asymptotic normality to hold. If these conditions hold, then many other types of scores, other than ranks, can be used. These conditions were relaxed by the principal investigator to allow normal scores to be included, in the summer of 1992.

The fifth objective was to derive methods for computing ARE for the rank-transformed balanced incomplete block design. This was accomplished by the principal investigator in the summer of 1992, by showing that the same ARE formulas hold for balanced incomplete block designs as were derived by other researchers in previous years for the rank transformation in randomized complete block designs. Thus the numerical computations in those previous papers carry over to this design also, and further computations are unnecessary.

The sixth objective was to extend some of these results to the general linear model. Some exact results, that apply to all rank transformation procedures, were obtained by the principal investigator and by a graduate student working under the PI's direction. At the same time the graduate student was able to show that the rank transformation does not work for tests for interaction in a two-way layout in which both factors are present. Thus a general extension of the rank transformation to the general linear model will not be possible.

C. LIST OF ALL PUBLICATIONS AND TECHNICAL REPORTS

W. J. Conover, "Some Limitations of the Rank Transformation Test for Interaction," published in Proceedings of the Thirty-Seventh Conference on the Design of Experiments in Army Research Development and Testing, held in Vicksburg Mississippi, October 1992

W. J. Conover, "The Rank Transformation in Balanced Incomplete Block Designs," published in Proceedings of the Thirty-Eighth Conference on the Design of Experiments in Army Research Development and Testing, held in Santa Monica California, October 1993.

D. LIST OF ALL PARTICIPATING SCIENTIFIC PERSONNEL SHOWING ANY ADVANCED DEGREES EARNED BY THEM WHILE EMPLOYED ON THE PROJECT

Neal W. Blackwood, Graduate Research Assistant. (No advanced degrees were earned while employed on this project.)

W. J. Conover, Principal Investigator.

E. THERE WERE NO INVENTIONS ASSOCIATED WITH THIS PROJECT.